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Materials (piping and joints) for waste-piping systems are evaluated and a material or materials best qualified for above ground service in health research facilities are recommended. Evaluation is based on cost and performance because the potential value of any material depends on its ability to compete in both areas. In general, the following criteria are considered important to most health research facility applications--(1) corrosive resistance, (2) mechanical strength, (3) useful life, (4) cost, including material, installation, and maintenance, and (5) other considerations. Interpretation of this criteria depends somewhat on applications and individual circumstances; several examples are cited. (RH)

Laboratory Design Notes

Distributed in the interest of improved research laboratory design

FOR PIPING CORROSIVE WASTES... Glass, Metal or Plastic?

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PIPE is being used for a variety of applications and environmental conditions, ranging from the underground transmission of water and petroleum products to the transfer of corrosive chemicals in industrial processing plants. No longer is the choice of pipe material limited to metals; in many instances new materials offer advantages which metals have never been able to provide.

We set out to evaluate materials (piping and joints) for waste-piping systems, and to recommend a material or materials best qualified for above-ground service in a health research facility such as the National Institutes of Health (NIH). Evaluation is based on cost and performance, because the potential value of any material depends on its ability to compete in both these areas.

In general, the following criteria are considered important to most health research facility applications: (1) corrosion resistance, (2) mechanical strength, (3) useful life, (4) cost–including material, installation, and maintenance, and (5) other considerations. Interpretation of these criteria will depend somewhat on application and circumstances, as indicated by the examples which follow.

In a research facility, for example, corrosion resistance means protection against such chemicals as mineral acids, bases, salts, organic solvents, and other active compounds disposed of via the laboratory sink or used in functions such as glassware washing. By contrast, many corrosion-resistant materials in other applications must protect only against a single compound or, at most, a single class of compounds.

As a second example, consider the effect of frequent alterations in both space and utilities in a research facility. Under these circumstances, it is erroneous to consider a material that lasts for the life of the building. Changes in plumbing during conversion of offices to laboratories and vice versa will necessitate replacement of pipe probably long before the end of its useful life.

Possible Materials

Three materials–glass, plastics, and metals–were compared. Although there are other possibilities such as cements, asbestos, ceramics, wood, and lined metal, these were not considered strong contenders.

Each of the three categories contains numerous similar materials, each varying slightly in chemical composition, physical properties, and other characteristics.

For example, there are hundreds of varieties of glass; two notable examples are soda (soft) glass and pyrex (hard) glass. Some of the more important types of glass are: silica, soda-lime-silica, lead-alkali, alumino-silicate, borosilicate, and phosphate. Borosilicate has, because of its properties, revolutionized glass application. Improved shock resistance

CORROSION RESISTANCE OF PIPE MATERIALS

Absence of U or F denotes satisfactory performance.

	Salt Solutions	Soap and Detergents	Strong Alkali	Dilute Acid	Sulfates	Bleach Solutions	Caustic Solutions	Alcohols and Glycol	Strong Acids	Organic Solvents	Esters and Ketones
Polyethylene								U		U	U
Polyvinyl chloride									F	U	U
Vinylidene chloride										F	F
Carbon steel	U					U			U		
Cast iron				F		U			F		
Stainless steel (18-8)	1			F					F		
Copper		F	F	F		F	F		U	F	
Duriron			2						2		
Glass (Pyrex)			2						2		

U — Unsatisfactory
F — Fair
1 — Stainless steel is susceptible to chloride ion stress corrosion
2 — Both glass and Duriron, having high silicon content, are susceptible to attack by strong hot alkalies and hydrofluoric acid.

Table I. At left: Comparative corrosion resistance of plastic, metal, and glass pipe.

Table II. Working pressure and maximum working temperature for three types.

WORKING PRESSURES AND TEMPERATURES

Material	Allowable* Working Pressure at Max. Working Temperature (psi)	Maximum* Working Temperature (F)
Glass	15**	250
Polyethylene (Sch. 40)	25	160
Polyvinyl chloride (Sch. 80)	55	180
Cast Iron	150	300
Carbon Steel (Sch. 40)	500	650

**Two-in. (nominal) dia pipe*
***Joints are guaranteed for 250 F, 15 psi service; tested to 22 psi at ambient temperature.*

PIPE AND FITTING COSTS

Material	Pipe Cost[1] per ft	Cost of Fittings 90-deg Ell	45-deg Ell	Tee	Coupling	Total[2] Pipe & Fitting
Polyethylene Sch. 40 (fusion joint)	$ 0.71	$ 2.80	$ 2.40	$ 3.54	$ 1.41	$88.88 (1962)
Wrought Iron Black (screw joint)	0.94	2.79	3.03	4.04	1.30	113.48 (1960)
Wrought Iron Galvanized (screw joint)	0.99	3.40	3.67	4.89	1.55	122.65 (1960)
Cast Iron, Heavy (packed joint)	1.21	1.44	1.12	2.08	—	130.60[3] (1962)
Cast Iron, Heavy (screw joint)	1.25	1.68	1.68	2.96	1.68	137.64 (1962)
Polyvinyl chloride Sch. 80 (screw joint)	1.26	2.56	2.56	2.96	2.09	142.16 (1963)
Glass, regular	2.70	7.00	7.00	12.00	—	322.00 (1963)
Copper "L"	2.88	4.60	2.80	5.40	2.00	315.40 (1962)
Duriron (packed joint)	6.25	10.20	10.20	13.62	—	693.04[3] (1962)

1—Size of pipe, 2 in. Prices of pipe and fittings do not reflect quantity discounts.
2—Includes: cost of 100 ft of pipe, 3 90-deg ells, 1 45-deg ell, and 2 tees; applicable year indicated in ( ).
3—Does not include cost of joint compound.

Table III. Pipe costs are shown for various fittings—90- and 45-deg ells, tees, couplings.

FOR PIPING CORROSIVE WASTES

and chemical stability have led to its use in piping and pump impellers.

Two broad divisions in the field of plastics are thermosetting and thermoplastic compounds. Typical thermosetting materials by generic designation are phenolics, polyesters, and epoxies. Thermoplastics include polyethylene, acrylonitrile-butadiene-styrene (ABS), polyvinyl chloride, butyrates, Saran, nylon, Teflon, and recently introduced polypropylene, Penton, Lexan and Delrin.

In the third category, metals, each has distinctive properties. For analysis, it is best to separate the ferrous from the nonferrous materials. In the ferrous class are: wrought iron, nickel steel, and stainless steel (martinsitic, ferritic, and austenitic). All of these materials have certain corrosion-resistant properties, generally are regarded as selective. Nonferrous materials include: aluminum, copper and bronzes, nickels, monel, inconel, titanium, and zirconium.

Corrosion Resistance

Waste piping in a health research facility such as the NIH is subjected to a wide diversity of wastes. The nature of wastes, constant elevated waste temperatures, and other factors subject piping to an environment more severe than industrial service.

Characteristic laboratory wastes include: acids (both organic and inorganic), alkalies, organic solvents, and a host of other chemicals. In addition, hot water and steam condensate, while they are not necessarily corrosive, may contribute to early piping failure.

In the over-all corrosion picture as shown in Table I, both glass and Duriron offer superior protection. However, these materials are not completely impervious or inert. Their silicon content renders them susceptible to attack from hydrofluoric acid and strong, hot alkalies. Stainless steel is considered inferior to both glass and Duriron. It is subject to pitting and subsequent penetrating attack by

ERECTION COSTS—TWO-INCH PIPE

Material and Type of Pipe	Labor (Man-hours per linear ft)
Metal	
Wrought iron Sch. 40	0.40
Wrought iron Sch. 80	0.45
Nonferrous (copper, brass)	0.45
Plastic	
Polyvinyl chloride (screw connection)	0.45
Polyethylene (weld connection)	0.45
Glass	0.60

Table IV. Erection costs for two-in. pipe are based on man-hours per linear ft.

chloride ion, which can lead eventually to stress-corrosion cracking.

Plastics, good protection against acids and many chemicals, have a notable weakness to organic solvents, esters, and ketones. One plastic having fair solvent resistance, (see Table I) is vinylidene chloride (Saran). Unfortunately it is expensive and considered uneconomical.

Our experience demonstrates the lack of corrosion protection afforded by galvanized pipe. In one installation, after only a few years' use, failures occurred in runouts and stacks subjected to normal (and in some cases severe) laboratory service. Replacement of stacks with Duriron and runouts with cast (gray) iron has practically eliminated failures even under severe service.

Mechanical Properties

Both plastic piping and glass joints have significant pressure and temperature limitations. These two variables determine the allowable working hoop stresses in plastic pipe installations. Typical working pressures and temperatures for various materials are tabulated in Table II. Since excessive hoop stresses are most likely to occur in stacks (risers) rather than runouts (horizontals), stack applications should receive careful consideration. Thermal expansion in long runs of plastic pipe should not be overlooked, since buckling from expansion or fracture from contraction may occur.

Thermal effects reducing allowable working pressure for a plastic are significant. Allowable working pressure for 2-in. Schedule 40 polyethylene pipe is 75 psi at 75 F, but is only 25 psi at 160 F.

Another mechanical limitation of plastics and glass is "notch sensitivity." Surface scratching, either internal or external, produces unavoidable stress concentrations. Under additional applied stress such scratches may initiate fracture. In cleaning glass pipe, surface scratching must be avoided; otherwise, the pipe may fracture from its own internal, unbalanced stress system.

Useful Life

Something should be said about the useful life factor, especially as it applies to NIH. Historically, a laboratory is "fluid" space—it is subject to rearrangement aimed at adapting the space to new or changing research programs. Relocation may lead to premature replacement of waste piping. Proper regard for this fact could lead to the selection of a material whose total utility is realized either at the time of replacement or upon reuse.

Any cost study should include both material and installation costs. Shelf cost of both pipe and fittings in a competitively priced material is about one-half the cost of the complete system, including installation, provided the system consists principally of pipe and fittings.

A detailed breakdown of pipe and fitting costs for the most prominent materials is presented in Table III. Costs do not reflect quantity discounts, which may reach 50 per cent. The size of pipe, the number of fittings (of each type), and the length of pipe have been arbitrarily chosen. In general, pipe thicknesses for the various materials are comparable, except that the price of polyethylene pipe is based on Schedule 40 (0.154-in wall thickness), not Schedule 80 (0.218-in. wall thickness) pipe, which partly accounts for its favorable price figure.

Table V. Figures on joint costs for two-in. pipe based on man-hours/coupling.

JOINT COSTS—TWO-INCH PIPE

Type of Joint and Material	Labor (Man-hours per coupling)
Compression (glass)	0.85
Poly-fusion (plastic)	1.00
Screw thread (plastic)	1.00
Screw thread (metal)	
Sch. 40	1.00
Sch. 80	1.20
Weld or Sweat (Ferrous and Nonferrous)	1.20
Bell and Spigot (3-in. dia metal)	1.75

Installation

Installation cost comparisons are much more difficult to obtain because of the many variables affecting the total installation price. There are such items as: distribution and handling; erection; preparation and joining; and hangers or supports. Each of these contributes to the total installation cost in terms of man-hours.

Distribution and handling. Included in distribution and handling are: unloading an open carrier within a short distance (50 ft) from an assigned storage space (on the site); stacking pipe or packages on a loading platform; and transportation from storage space to site installation.

Factors reflected by the data are threefold: (a) weight of pipe, (b) length of pipe, and (c) ease of handling. The relative weights of identical pipe lengths of different materials are indicated generally by material densities (or specific gravities): plastics, 1.0; glass, 2.5; and metals, 8.0.

Plastics and most metals are manufactured in 20-ft lengths, while glass is available in 5- or 10-ft lengths. Obviously, the shorter pipe lengths require more boxes or bundles for an equivalent length of pipe. In handling glass it is necessary to exercise more caution than in handling plastics or metals (Duriron excepted), since susceptibility to fracture is greater.

Table VI. Hanger costs for two-in. pipe based on man-hours per linear foot.

HANGER COSTS—TWO-INCH PIPE

Type of Pipe	Labor (Man-hours per linear foot)
Metal (screw joint)	0.07 (12-ft spacing)
Glass	0.10 (8-10 ft spacing)
Plastic	0.30 (continuous support)

Therefore, as expected, plastics are by far the cheapest to distribute and handle. Glass, on the other hand, will be most expensive (Duriron excepted) in spite of its relatively low specific gravity.

Erection. This item covers threading, cementing, alignment, and making joints, but excludes labor necessary to tighten joints. The data in Table IV present a comparison of straight runs of pipe with no allowance for fittings.

Joints. One of the major contributing costs in any installation is the time required to make a connection (joint). For cost data, refer to Table V. These data are applicable to joining like materials, but not dissimilar materials.

Hangers. Piping, regardless of material, requires supports or hangers, particularly in horizontal pipe runs and with materials of low flexural strength. As indicated in Table VI, plastics require continuous support because strength falls off sharply at elevated temperature. Metals, particularly screw joints, are able to tolerate minimal support and thus require fewer man-hours to install the necessary hangers.

Cost Summary

Summation of the four preceding factors establishes a ready comparison of the selected materials, but these estimates are neither absolute nor directly applicable to specific cases. For example, no attempt has been made to differentiate between the erection costs for risers and runouts or for factors such as erection height, congestion, and labor conditions.

Keeping these facts in mind, the installation cost analysis shows: metal (screw joint), 1.0; glass (compression joint), 1.25; and plastic (unspecified type joint), 1.33; where 1.0 represents the least cost.

On the other hand, based solely on pipe and fitting costs indicated in Table III, relative costs are: plastic (polyethylene), 1.0; cast iron (screw joint), 1.8; and borosilicate glass, 3.8.

The total price picture, combining installation and material costs, shows: plastic, 1.0; metal, 1.2;

and glass, 2.2. As indicated, the plastic material is polyethylene, the metal is cast iron with screw joint coupling, and the glass is borosilicate.

Secondary Factors

In any choice of pipe material, several important factors are frequently overlooked or given little consideration. These "secondary" factors may overshadow the major considerations in certain instances.

One such factor is the method of coupling sections of pipe. The joint is an important link in the pipe system, since it may be the weakest one. Causative agents of failure are more numerous, if not more severe, at the joint than over the straight cylindrical section of pipe. Threading, a technique commonly used to join metal pipe (and occasionally plastics) and fusion by heat or solvent both may create built-in stresses on a reduced pipe-wall thickness. Discontinuities of the inside pipe surface and crevices at couplings and joints provide an ideal environment for corrosion-causing sludge or sediment and moisture to collect.

To ensure a competent job of joining pipe, standards should be established in the form of detailed layout drawings and specifications. Work inspectors should be familiar with what constitutes good workmanship practices, quality products, and acceptable installation.

A Look at the Future

Neither plastic nor glass pipe can entirely replace metal pipe for all waste and drainpipe applications in a research facility. From a long-range viewpoint we can expect both plastic and glass pipe to grow in stature and gain greater acceptance. Plastics will be hampered by the lack of suitable engineering test information describing pipe performance, but the industry will eventually obtain these data.

Table VII. Criteria given in the table for the three studied materials are related to corrosion resistance, mechanical properties, useful life, ease of installation, and cost.

MATERIALS CRITERIA

Property	Metal	Plastic	Glass
1. Corrosion resistance	Good	Good	Superior
(a) Weaknesses	Mineral acids, alkalis, saline solutions	Organic solvents esters, ketones	Hydrofluoric acid, strong alkalies
(b) Drawback	Electrolytic corrosion	Surface ablation	— — — —
2. Mechanical properties	Superior	Fair	Fair
(a) Weaknesses	Some are brittle	High temperatures and pressures; high coefficient of thermal expansion	Brittleness; high pressure
3. Useful life	Long	Good*	Good*
4. Ease of installation	Easy	Must be continuously supported	Requires special skills and equipment
5. Cost			
(a) Material	Moderate except for high silicon types	Low	High
(b) Installation	Low, except for caulked joint	High	Moderate
(c) Material plus installation	Moderate	Low	High

**Neither plastic nor glass have seen service life comparable to metals at NIH.*

With these facts in mind, these are our recommendations:

1. It does not appear timely to make widespread transition to either glass or plastics.

2. For most NIH applications gray cast iron is considered an optimum material. Its selection in a screw-threaded style joint is recommended for runouts, while the caulked joint is recommended for risers.

3. In unique applications (e.g., handling extremely corrosive wastes) or where unusual circumstances prevail, glass, Duriron, plastic, or any other material should be considered for possible advantages and superior performance.

4. There is no objection to the use of either plastic or glass waste pipe provided the known limitations of each are recognized and proper contractual safeguards implemented. Specifically, polyethylene should not be employed where:
   a. internal pressures may exceed 20-25 psi
   b. ambient temperatures, external or internal, may exceed 170 F
   c. the presence of a combustible drain pipe would contribute to fire hazard
   d. rodents may possibly gain access to piping (rats have been reported to chew polyethylene).

5. Plastic pipe may be used in applications exclusive of environmental conditions previously stated with the following contractual conditions:
   a. Detailed drawings and specifications on workmanship and installation for each item should be included in the plans
   b. Any substantial contemplated use of plastic pipe should be included as an alternate bid item so that actual in-place cost can be evaluated prior to acceptance. **End**

Additional copies of this leaflet may be obtained from: Office of Architecture and Engineering, Division of Research Facilities and Resources, National Institutes of Health, Bethesda, Maryland 20014

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